CLAIMS

1. A lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second, movable object table provided with a substrate holder for holding a substrate;

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate; and

a positioning system for moving said second object table between an exposure station, at which said projection system can image said mask portion onto said substrate, and a measurement station; characterized in that

said second object table has a physical reference surface fixed thereto;

and by:

height mapping means located at said measurement station and constructed and arranged to measure the height, relative to said physical reference surface, of a plurality of points on the surface of a substrate held on said substrate holder and to create a height map thereof;

position measuring means located at said exposure station for measuring the position of said physical reference surface in a first direction substantially perpendicular to said substrate surface, after movement of said second object table to said exposure station; and

control means constructed and arranged to control the position of said second object table in at least said first direction, during exposure of said target portion, in accordance with said height map and said position measured by said position measuring means.

2. Apparatus according to claim 1 wherein said control means is further arranged to control the tilt of said second object table about at least one axis perpendicular to said first direction in accordance with said height map.

3. Apparatus according to claim 1 or 2 wherein said height mapping means comprises a level sensor constructed and arranged to simultaneously measure the position in said first direction of a linear array of points.

4. Apparatus according to claim 1, 2 or 3, wherein said height mapping means comprises a level sensor constructed and arranged to measure the position of a measurement beam reflected by the surface whose position in said first direction is to be measured.

5. Apparatus according to claim 4 wherein said level sensor comprises: a projection grating; projection optics for projecting an image of said projection grating onto the surface whose position in said first direction is to be measured; a detection grating, detection optics for focusing light reflected by said surface to form on said detection grating an image of said projection grating; and a detector for detecting Moiré patterns formed by the overlay of said image of said projection grating on said detection grating.

6. Apparatus according to claim 5 wherein said level sensor further comprises a radiation source constructed and arranged to illuminate said projection grating with polychromatic radiation and wherein said projection optics and said detection optics consist essentially of reflective optical elements.

7. Apparatus according to any one of the preceding claims wherein said height mapping means comprises a level sensor for detecting the position in said first direction of the surface of said substrate at said plurality of points and position detection means for detecting the position in said first direction of said second object table simultaneously with measurements by said level sensor.

8. Apparatus according to claim 7 wherein said position detection means comprises an interferometer.

9. Apparatus according to any one of the preceding claims wherein said position measuring means comprises an image sensor mounted to said second object table and said physical reference surface comprises an upper surface of said image sensor.

10. Apparatus according to any one of the preceding claim, wherein said position measuring means is constructed and arranged to measure the position of said physical reference surface relative to the focal plane of said projection system.

11. Apparatus according to any one of the preceding claims wherein said second object table has a plurality of spaced-apart physical reference surfaces; and said height mapping means is constructed and arranged to measure the height of said plurality of points relative to a reference plane defined by said plurality of physical reference surfaces.

12. Apparatus according to any one of the preceding claims further comprising:

a second height mapping means located at said exposure station constructed and arranged to measure the height, relative to said physical reference surface, of said plurality of points on the surface of a substrate held on said substrate holder and to create a height map thereof; and

calibration means constructed and arranged to compare height maps of a single substrate prepared by each of said first and second height mapping means to derive a relative calibration for separate position detection systems provided at said measurement and exposure stations.

13. A method of manufacturing a device using a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second, movable object table provided with a substrate holder for holding a substrate; and

a projection system for imaging irradiated portions of the mask onto target portions of the substrate at an exposure station; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table; and

imaging said irradiated portions of the mask onto said target portions of the substrate; characterized by the steps of:

before said step of imaging, generating, with the second object table at a measurement station, a height map indicating the height of a plurality of points on the substrate surface relative to a physical reference surface on said second object table;

moving the second object table to said exposure station and measuring the position of said physical reference surface in a first direction substantially perpendicular to said substrate surface; and

during said step of imaging, positioning the second object table in at least said first direction by reference to said height map and said measured position in said first direction of said physical reference surface.

14. A method according to claim 13 wherein, during said step of imaging, said second object table is oriented about at least one axis perpendicular to said first direction by reference to said height map.

15. A method according to claim 13 or 14 wherein said second object table is positioned during said imaging step so as to minimize the squared defocus integrated over the area of said target portion, wherein the defocus comprises the distance in said first direction between the focal surface of said projection lens and the surface of said substrate.

16. A method according to claim 13 or 14 wherein said step of imaging comprises scan imaging a slit image onto said substrate, and said second object table is positioned during said imaging step so as to minimize the squared defocus integrated over the duration of said scanning exposure and the area of said slit image, wherein the defocus comprises the distance in said first direction between the focal surface of said projection lens and the surface of said substrate.

17. A method according to any one of claims 13 to 16 wherein said step of generating a height map comprises the substeps of:

measuring the position in said first direction of each of said plurality of points on said substrate surface;

simultaneously with each measurement of the position of a point on said substrate surface, measuring the position in said first direction of said second object table; and

subtracting each measured position of said second object table from the corresponding measured position of said substrate surface to generate said height map.

18. A method according to claim 17 wherein said step of generating a height map comprises the initial step of measuring the position in said first direction of said physical reference surface and simultaneously the position in said first direction of said second object table.

19. A method according to any one of claims 13 to 18 comprising the further steps, before said step of generating a height map, of:

measuring the height of a plurality of points on said wafer surface adjacent the perimeter of areas on said substrate that are to be exposed, and determining from the measured heights an overall height and tilt for said substrate and/or local height or tilt values in certain regions of said substrate surface whose height is to be mapped.

20. A method according to any one of claims 13 to 19 further comprising the step, before said step of generating a height map, of calibrating a level sensor to be used in generating said height map by using said level sensor to make a plurality of measurements of the vertical position of at least one predetermined point on said substrate surface with the second object table being positioned at different vertical positions for different ones of said plurality of measurements.

21. A method according to claim 20 wherein said step of calibrating is performed for a plurality of different exposure areas on said substrate and respective resulting

calibration corrections are applied in generating the height map for exposure areas corresponding in type to those for which the calibration was performed.

22. A device manufactured according to the method of any one of claims 13 to 21.

23. A method of calibrating a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second, movable object table provided with a substrate holder for holding a substrate; and

a measurement station having a first position detection system for measuring the position of said second object table at said measurement station;

an exposure station having a projection system for imaging irradiated portions of the mask onto target portions of the substrate and a second position detection system for measuring the position of said second object table at said exposure station; the method comprising the steps of:

providing a substrate to said second object table;

at said measurement station, generating a first height map of said substrate by measuring the position in a first direction, substantially perpendicular to the surface of said substrate, of a plurality of points on said substrate surface and simultaneously measuring the position of said second object table using said first position detection system;

at said exposure station, generating a second height map of said substrate by measuring the position in said first direction of said plurality of points on said substrate surface and simultaneously measuring the position of said second object table using said second position detection system; and

comparing said first and second height maps to calibrate said first and second position detection systems.

24. A method of manufacturing devices using a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first object table provided with a mask holder for holding a mask;

a second, movable object table provided with a substrate holder for holding a substrate; and

a projection system for imaging irradiated portions of the mask onto target portions of the substrate; the method comprising the steps of:

providing a mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table; and

imaging said irradiated portions of the mask onto said target portions of the substrate;

said steps of providing a substrate and imaging being repeated to expose a plurality of substrates; characterized by the steps of:

generating, for each substrate provided to second object table, a height map indicating the height of a plurality of points on the substrate surface; and

comparing the height maps of successively provided substrates to detect correlations in the locations of any unflatnesses that may be indicative of contamination or systematic faults of said second object table.

25. A lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first, movable object table provided with a mask holder for holding a reflective mask;

a second, object table provided with a substrate holder for holding a substrate; and

a projection system for imaging an irradiated portion of the mask onto a target portion of the substrate; characterized by

height mapping means constructed and arranged to measure the height, relative to a reference surface, of a plurality of points on the plane of a reflective mask held on said mask holder and to create a height map thereof; and

control means constructed and arranged to control the position of said first object table in at least said first direction, during exposure of said target portion, in accordance with said height map.

26. A method of manufacturing a device using a lithographic projection apparatus comprising:

a radiation system for supplying a projection beam of radiation;

a first, movable object table provided with a mask holder for holding a reflective mask;

a second object table provided with a substrate holder for holding a substrate; and

a projection system for imaging irradiated portions of the mask onto target portions of the substrate; the method comprising the steps of:

providing a reflective mask bearing a pattern to said first object table;

providing a substrate having a radiation-sensitive layer to said second object table; and

imaging said irradiated portions of the mask onto said target portions of the substrate; characterized by the steps of:

before said step of imaging, generating, a height map indicating the height of a plurality of points on the mask surface relative to a reference plane on said first object table; and

during said step of imaging, positioning the first object table in at least said first direction by reference to said height map.